General Technical Guidance for Treatment Measures

The technical guidance in this Chapter applies to all types of stormwater treatment measures.

This chapter contains general technical information regarding stormwater treatment measures for all types of new development and redevelopment projects. It includes the following topics:

- Hydraulic sizing criteria,
- The applicability of non-landscape based treatment measures,
- Guidance regarding “treatment trains,”
- Infiltration guidelines,
- Using underdrains,
- Using low-flow systems,
- Selecting and maintaining plantings in landscape-based treatment measures,
- Mosquito control requirements,
- Incorporating treatment with hydromodification management measures, and
- Getting water into stormwater treatment measures.

5.1 Hydraulic Sizing Criteria

The stormwater treatment measures must be sized to treat stormwater runoff from relatively small sized storms that comprise the vast majority of storms. The intent is to treat most of the stormwater runoff while recognizing that it would be infeasible to size stormwater treatment measures to treat runoff from very large storms that occur every few years. (See Section 5.6 for more information on how stormwater treatment measures that are sized to treat runoff from small, frequent storms can be designed to also handle flows from large, infrequent storms.)

How Much of Project Site Needs Stormwater Treatment?

The Municipal Regional Stormwater Permit requires that, for all “Regulated Projects” the project site must receive stormwater treatment. Municipalities may require stormwater

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1 “Regulated Projects” are projects that create and/or replace 10,000 square feet or more of impervious surface. Beginning December 1, 2011, this threshold is reduced to 5,000 square feet of impervious surface for surface parking areas, restaurants, auto service facilities, and retail gasoline outlets.
treatment for projects that are smaller than the Regulated Project threshold, and in these cases, stormwater treatment is required to the maximum extent practicable (MEP). Exceptions to the stormwater treatment requirement for Regulated Projects are pervious areas that are “self-treating” (including areas of pervious pavement with a hydraulically-sized aggregate base layer) as described in Section 4.1, and “self-retaining areas” designed to store and infiltrate runoff from rooftops or paved areas as described in Section 4.2. Other than “self-treating areas” and “self-retaining areas,” **ALL AREAS AT A PROJECT SITE** must receive stormwater treatment.

Treating runoff from areas that are downgradient from stormwater treatment measures, such as driveway entrances, can be challenging. Consider using pervious pavement in these areas, using interceptor tree credits (see Section 4.5) to account for the amount of impervious surface created and/or replaced by driveway entrances. Opportunities to provide offsite treatment of the applicable amount of impervious surface may also be considered, as described in Chapter 9, Alternative Compliance.

**Flow-Based Versus Volume-Based Treatment Measures**

For hydraulic sizing purposes, stormwater treatment measures can be divided generally into three groups: flow-based, volume-based, and treatment measures that use a combination of flow and volume capacity. The **flow-based treatment measures** remove pollutants from a moving stream of stormwater, and the treatment measures are sized based on hourly or peak flow rates. Examples of flow-based treatment measures include media filters and high flow-rate tree well filters. The **volume-based treatment measures** detain stormwater for periods of between 24 hours and 5 days, so the sizing is based on detaining a large volume of water for treatment and/or infiltration to the ground. Examples of volume-based stormwater treatment measures include infiltration trenches and rainwater harvesting systems. Flow-through planters and bioretention areas are typically sized using flow-based hydraulic sizing criteria, but in constrained areas they may use a **combination of flow and volume capacity** for stormwater treatment. Table 5-1 shows which hydraulic sizing method is appropriate for commonly used stormwater treatment measures.

<table>
<thead>
<tr>
<th>Type of Treatment Measure</th>
<th>Type of Hydraulic Sizing Criteria to Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1 Bioretention</td>
<td>Flow-based or combination flow and volume</td>
</tr>
<tr>
<td>6.2 Flow-through planter</td>
<td>Flow-based or combination flow and volume</td>
</tr>
<tr>
<td>6.3 Tree well filter</td>
<td>Flow-based</td>
</tr>
<tr>
<td>6.4 Infiltration trench</td>
<td>Volume-based</td>
</tr>
<tr>
<td>6.5 Extended detention basin</td>
<td>Volume-based</td>
</tr>
<tr>
<td>6.6 Pervious paving</td>
<td>Volume-based</td>
</tr>
<tr>
<td>6.7 Grid pavements</td>
<td>Volume-based</td>
</tr>
<tr>
<td>6.8 Green roof</td>
<td>Volume-based</td>
</tr>
<tr>
<td>6.9 Rainwater harvesting</td>
<td>Volume-based</td>
</tr>
<tr>
<td>6.10 Media filter</td>
<td>Flow-based</td>
</tr>
<tr>
<td>6.11 Subsurface infiltration system</td>
<td>Volume-based</td>
</tr>
</tbody>
</table>
Volume-Based Sizing Criteria

The Municipal Regional Stormwater Permit specifies two alternative methods for hydraulically sizing volume-based stormwater treatment measures. One of the permit-approved methods, the “Urban Runoff Quality Management Approach,” is based on simplified procedures that are not recommended for use when information is available from continuous hydrologic simulation of runoff using local rainfall records (see “Urban Runoff Quality Management, WEF Manual of Practice No. 23/ASCE Manual and Report on Engineering Practice No. 87.”) Because the results of continuous simulation modeling based on local rainfall are available, the Clean Water Program recommends the use of the “California Stormwater BMP Handbook Approach,” or “80 percent capture method,” shown in the text box.

Please note that the Clean Water Program’s member agencies may also allow project applicants to use an even simpler sizing method for sizing flow/volume-based treatment measures such as flow-through planters and bioretention areas, which is described below, under the heading, Simplified Sizing Methods.

The 80 percent capture method should be used when sizing infiltration trenches, rainwater harvesting systems, or extended detention basins. The 80 percent runoff value is determined by the Storage, Treatment, Overflow, Runoff Model (STORM), which uses continuous simulation to convert rainfall to runoff based on local rainfall data. STORM was developed by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers.


To size volume-based treatment measures, use the following steps, which may be performed using the volume-based sizing criteria Excel worksheet provided in Appendix C.

1. Mean Annual Precipitation
   - Determine the mean annual precipitation (MAP) for the project site using the Mean Annual Precipitation Map of Alameda County (Appendix D). Use the Oakland Airport unit basin storage volume values from Table 5-2 if the project location’s mean annual precipitation is 16.4 inches or greater and the San Jose values if it is less than 16.4 inches.
   - In order to account for the difference between MAP of the project site and the two rainfall locations shown, calculate the MAP adjustment factor by dividing the project MAP by the MAP for the applicable rain gauge, as shown below:

   \[
   \text{MAP adjustment factor} = \frac{\text{(project location mean annual precipitation)}}{(18.35 \text{ or } 14.4, \text{ as appropriate})}
   \]
2. **Effective Impervious Area for the Drainage Management Area**

- Based on the topography of the site and configuration of buildings, divide the site into drainage management areas (DMAs), each of which will drain to a treatment measure. Implement the steps below for each DMA with a volume-based treatment measure.

- Minimize the amount of landscaping or pervious pavement that will contribute runoff to the treatment measures. Refer to Sections 4.1 and 4.2 to design areas of landscaping or pervious pavement as "self-treating areas" or "self-retaining areas," so that they do not contribute runoff to the LID treatment measure and may be excluded from the DMAs for the treatment measures.

- For each DMA in which the area that will contribute runoff to the treatment measure includes pervious surfaces (landscaping or properly designed pervious paving), multiply the area of pervious surface by a factor of 0.1.

- For applicable DMAs, add the product obtained in the previous step to the area of impervious surface, to obtain the “effective impervious area.” (For DMAs that are 100% impervious, use the entire DMA area.)

3. **Unit Basin Storage Volume**

- The effective impervious area of a DMA has a runoff coefficient of 1.0. Refer to Table 5-2 to obtain the *unit basin storage volume* that corresponds to your rain gauge area. For example, using the Oakland Airport gauge, the unit basin storage volume would be 0.67 inches. Adjust the unit basin storage volume for the site by multiplying the unit basin storage volume value by the MAP adjustment factor calculated in Step 1.

- Calculate the *required capture volume* by multiplying the effective impervious area of the DMA calculated in Step 2 by the adjusted unit basin storage volume. Due to the mixed units that result, such as acre-inches, it is recommended that the resulting volume be converted to cubic feet for use during design. For example, say you determined the adjusted unit basin storage volume to be 0.5 inches, and the effective impervious area draining to the bioretention facility is 7,000 square feet. Then the required capture volume would be 0.5 inches \( \times \) (1 foot/12 inches) \( \times \) 7,000 square feet = 292 cubic feet.

<table>
<thead>
<tr>
<th>Location</th>
<th>Mean Annual Precipitation (inches)</th>
<th>Coefficient of 1.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oakland Airport</td>
<td>18.35</td>
<td>0.67</td>
</tr>
<tr>
<td>San Jose</td>
<td>14.4</td>
<td>0.56</td>
</tr>
</tbody>
</table>

4. **Depth of Infiltration Trench or Pervious Paving Base Layer**

If you are designing an infiltration trench, or area of pervious paving that will receive runoff from adjacent impervious surfaces, determine the surface area that is available for the trench, or the area of pervious paving. Given that surface area, the depth required for the trench, or for the rock base below the pervious paving, may be calculated by dividing the required capture volume by 0.35 (which represents the assumed void space available within the rock-filled trench or base), and then dividing the rock volume by the surface area of the proposed trench or area of pervious paving.

**Flow-Based Sizing Criteria**

The Municipal Regional Stormwater Permit specifies three alternative methods for hydraulically sizing flow-based stormwater treatment control measures, such as flow through planter boxes, and media filters. These three methods are described in Table 5-3.

The percentile rainfall intensity method is based on ranking the hourly depth of rainfall from storms over a long period, and determining the 85th percentile hourly rainfall depth and multiplying this value by two. In the Bay Area, this value is generally around 0.2 inches/hour at low elevation rain gauges. The permit also allows the use of 0.2 inches/hour as one of the three alternative methods regardless of the results from calculating values from local rainfall depths.

<table>
<thead>
<tr>
<th>Flow-based Sizing Criteria</th>
<th>Description</th>
<th>Practice Tips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentile Rainfall Intensity Method</td>
<td>Ranks the hourly depth of rainfall from storms over a long period, determines the 85th percentile hourly rainfall depth, and multiplies this value by two.</td>
<td>This approach requires hydrologic studies that have not been conducted in Alameda County. Results of studies in other Bay Area locations showed a rainfall intensity of about 0.2 inch/hour.</td>
</tr>
<tr>
<td>0.2 Inch-per-Hour Intensity Method (Recommended Method)</td>
<td>Simplification of the Percentile Rainfall Intensity Method.</td>
<td>The 4 percent method, which is recommended for use throughout Alameda County, is derived from this approach.</td>
</tr>
<tr>
<td>10% of the 50-year peak flow rate (“Factored Flood Flow Approach”)</td>
<td>Rainfall intensity is determined using Intensity-Duration-Frequency curves published by the local flood control agency or climactic data center.</td>
<td>This approach may be used if the 50-year peak flow has been determined. This approach has not been used locally.</td>
</tr>
</tbody>
</table>

**Sizing Bioretention Areas**

The simplified method for sizing bioretention areas and flow-through planters, known as the “4 percent method,” is based on a runoff inflow of 0.2 inches per hour, with an infiltration rate through the biotreatment soil of 5 inches per hour (0.2 in/hr divided by 5 in/hr = 0.04). Because
two of the permit allowed methods yield similar results and the third method requires data that may not be readily available, the **Clean Water Program recommends using the 4 percent method to design bioretention areas**, flow-through planters, and tree well filters that use biotreatment soil.

The 4 percent method requires the surface area of the treatment measure to be 4 percent of the impervious area that drains to it (1,750 square feet of bioretention area per impervious acre). If areas of landscaping or pervious paving contribute runoff to the treatment measure, the area of these pervious surfaces is multiplied by a factor of 0.1 to obtain the amount of “effective impervious area” (as described in the volume-based sizing approach earlier in this chapter).

**To apply the 4 percent method, use the following steps:**

1. Based on the topography of the site and configuration of buildings, divide the site into drainage management areas (DMAs), each of which will drain to an LID treatment measure. Implement Steps 2 through 5 for each DMA.
2. Minimize the amount of landscaping or pervious pavement that will contribute runoff to the LID treatment measures. Refer to Sections 4.1 and 4.2 to design areas of landscaping or pervious pavement as “self-treating areas” or “self-retaining areas,” so that they do not contribute runoff to the LID treatment measure and may be excluded from the DMAs for the treatment measures.
3. For each DMA in which the area that will contribute runoff to the treatment measure includes pervious surfaces (landscaping or pervious paving), multiply the area of pervious surface by a factor of 0.1.
4. For applicable DMAs, add the product obtained in Step 3 to the area of impervious surface, to obtain the “effective impervious area.”
5. Multiply the impervious surface (or effective impervious area in applicable DMAs) by a factor of 0.04. This is the required surface area of the LID treatment measure.

*Appendix C includes an example of sizing bioretention areas using the 4 percent method.*

**Sizing Other Flow-Based Treatment Measures**

Other flow-based stormwater treatment measures, such as media filters (where allowed on a project), are sized using the Rational Method, which computes the runoff resulting from the design rainfall intensity. The Rational Method formula is:

\[ Q = C i A \]

Where:
- \( Q \) = flow in cubic feet/second
- \( i \) = rainfall intensity in inches/hour
- \( C \) = composite runoff coefficient (unitless – see Table 5-4)
- \( A \) = drainage area in acres
To compute the water quality design flow, use the following steps:

1. Determine the **drainage area**, “A,” in **acres** for the stormwater treatment measure.

2. Determine the **runoff coefficient**, “C,” from Table 5-4. Note that it is more accurate to compute an area-weighted “C-factor” based on the surfaces in the drainage area, if possible, than to assume a composite C-factor.

3. Use a design intensity of **0.2 inches/hour** for “i” in the Q=CiA equation.

4. Determine the design flow (Q) using Q = CiA:
   
   \[ Q = [\text{Step 2}] \times 0.2 \text{ in/hr} \times [\text{Step 1}] = \underline{\text{____ cubic ft/sec}}^{2} \]

Table 5-4

<table>
<thead>
<tr>
<th>Type of Surface</th>
<th>Runoff Coefficients “C” factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roofs</td>
<td>0.90</td>
</tr>
<tr>
<td>Concrete</td>
<td>0.90</td>
</tr>
<tr>
<td>Asphalt</td>
<td>0.90</td>
</tr>
<tr>
<td>Grouted pavers</td>
<td>0.90</td>
</tr>
<tr>
<td>Pervious concrete</td>
<td>0.10</td>
</tr>
<tr>
<td>Pervious asphalt</td>
<td>0.10</td>
</tr>
<tr>
<td>Permeable interlocking concrete pavement</td>
<td>0.10</td>
</tr>
<tr>
<td>Grid pavements with grass or aggregate surface</td>
<td>0.10</td>
</tr>
<tr>
<td>Crushed aggregate</td>
<td>0.10</td>
</tr>
<tr>
<td>Grass</td>
<td>0.10</td>
</tr>
</tbody>
</table>

**Note:** These C-factors are only appropriate for small storm treatment design and should not be used for flood control sizing. When available, locally developed small storm C-factors for various surfaces may be used.

**Combination Flow and Volume Design Basis**

For projects on sites where infiltration should be avoided, or for which the agency determines that plans to maximize density will result in substantial environmental benefits, staff may allow the use of the combination flow and volume design basis for bioretention areas and flow-through planters that include a surface ponding area. In these treatment measures, volume-based treatment is provided when stormwater is stored in the

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2 Note that the Rational Method formula produces a result with units of “acre-in/hour”; however, the conversion factor from acre-in/hour to cubic feet/second is approximately 1.0.
The surface ponding area may be sized so that the ponding area functions to retain water before it enters the soil at the minimum 5 inches per hour required by MRP Provision C.3.c(2)(b)(vi). This may allow for a reduced footprint of the bioretention area or flow-through planter. However, it is recommended that agencies not approve any bioretention areas or flow-through planters sized using this method that propose a surface area that is less than 3 percent of the effective impervious area that drains to the treatment measure.

The 4 percent method for sizing bioretention areas and flow-through planters, in which the surface area of the treatment measure is designed to be 4 percent of the effective impervious area that drains to the treatment measure, is a flow-based sizing approach. This approach tends to result in the design of a conservatively large treatment measure because it does not account for any storage provided by the surface ponding area.

Provision C.3.d of the MRP specifies that treatment measures that use a combination of flow and volume capacity shall be sized to treat at least 80 percent of the total runoff over the life of the project, using local rainfall data. This sizing approach is best applied when using a continuous simulation hydrologic model to demonstrate that a treatment system is in compliance with C.3.d. However, when doing sizing calculations by hand, compliance with C.3.d. can be demonstrated by showing how the treatment system design meets both the flow-based and volume-based criteria.

To apply the combination flow and volume approach, use the following steps, which may be performed using the combination flow and volume sizing criteria Excel worksheet provided in Appendix C.

1. **Mean Annual Precipitation**
   - Determine the mean annual precipitation (MAP) for the project site using the Mean Annual Precipitation Map of Alameda County (Appendix D). Use the Oakland Airport unit basin storage volume values from Table 5-4 if the project

![Figure 5-1: Bioretention area, Emeryville (example of a combination flow- and volume-based treatment measure)](image-url)
In order to account for the difference between MAP of the project site and the two rainfall locations shown, calculate the **MAP adjustment factor** by dividing the project MAP by the MAP for the applicable rain gauge, as shown below:

\[
\text{MAP adjustment factor} = \frac{\text{(project location mean annual precipitation)}}{18.35 \text{ or } 14.4, \text{ as appropriate}}
\]

### 2. Effective Impervious Area for the Drainage Management Area

- Based on the topography of the site and configuration of buildings, divide the site into drainage management areas (DMAs), each of which will drain to a treatment measure. Implement the steps below for each DMA in which you will design a combined flow- and volume-based treatment measure.
- Minimize the amount of landscaping or pervious pavement that will contribute runoff to the treatment measures. Refer to Sections 4.1 and 4.2 to design areas of landscaping or pervious pavement as “self-treating areas” or “self-retaining areas,” so that they do not contribute runoff to the LID treatment measure and may be excluded from the DMAs for the treatment measures.
- For each DMA in which the area that will contribute runoff to the treatment measure includes pervious surfaces (landscaping or properly designed pervious paving), multiply the area of pervious surface by a factor of 0.1.
- For applicable DMAs, add the product obtained in the previous step to the area of impervious surface, to obtain the “**effective impervious area**.” (For DMAs that are 100% impervious, use the entire DMA area.)

### 3. Unit Basin Storage Volume

- The effective impervious area of a DMA has a runoff coefficient of 1.0. Therefore, refer to Table 5-4 to obtain the **unit basin storage volume** that corresponds to your rain gauge area. For example using the Oakland Airport gauge, the unit basin storage volume would be 0.67 inches. Adjust the unit basin storage volume by multiplying the unit basin storage volume value by the MAP adjustment factor calculated in Step 1.
- Calculate the **required capture volume** by multiplying the area of the DMA (or the effective impervious area if it includes landscaping), calculated in step 2, by the adjusted unit basin storage volume. Due to the mixed units that result, such as acre-inches, it is recommended that the resulting volume be converted to cubic feet for use during design. For example, say you determined the adjusted unit basin storage volume to be 0.5 inches, and the effective impervious area draining to the bioretention facility is 7,000 square feet. Then the required capture volume would be 0.5 inches \(\times\) (1 foot/12 inches) \(\times\) 7,000 square feet = 292 cubic feet.
Table 5-2 (repeated)
Unit Basin Storage Volume (Inches) for 80 Percent Capture with 48-Hour Drawdown Time

<table>
<thead>
<tr>
<th>Applicable Rain Gauge</th>
<th>Mean Annual Precipitation (inches)</th>
<th>Runoff Coefficient of 1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oakland Airport</td>
<td>18.35</td>
<td>0.67</td>
</tr>
<tr>
<td>San Jose</td>
<td>14.4</td>
<td>0.56</td>
</tr>
</tbody>
</table>

Source: CASQA 2003

4. **Duration of Rain Event**

- Assume that the rain event that generates the required capture volume of runoff determined in Step 3 occurs at a constant rainfall intensity of 0.2 inches/hour from the start of the storm (i.e., assume a rectangular hydrograph). Calculate the duration of the rain event by dividing the unit basin storage volume by the intensity. In other words, determine the amount of time required for the unit basin storage volume to be achieved at a rate of 0.2 inches/hour. For example, if the unit basin storage volume is 0.5 inches, the rain event duration is 0.5 inches \( \div 0.2 \) inches/hour = 2.5 hours.

5. **Preliminary Estimate of the Surface Area the Facility**

- Make a preliminary estimate of the surface area of the bioretention facility by multiplying the DMA’s impervious area (or effective impervious surface if applicable) by the 4 percent method sizing factor of 0.04. For example, a drainage area of 7,000 square feet of impervious surface \( \times 0.04 = 280 \) square feet of bioretention treatment area.

- Assume a bioretention area that is about 25% smaller than the bioretention area calculated with the 4 percent method. Using the example above, 280 – \( 0.25 \times 280 \) = 210 square feet.

- Calculate the volume of runoff that filters through the biotreatment soil at a rate of 5 inches per hour (the design surface loading rate for bioretention facilities), for the duration of the rain event calculated in Step 4. For example, for a bioretention treatment area of 210 square feet, with an infiltration rate of 5 inches per hour for a duration of 2.5 hours, the volume of treated runoff = 210 square feet \( \times 5 \) inches/hour \( \times (1 \text{ foot}/12 \text{ inches}) \times 2.5 \) hours = 219 cubic feet. (Note: when calculating ponding depth, the mulch layer is not included in the calculation.)

6. **Initial Adjustment of Depth of Surface Ponding Area**

- Calculate the portion of the required capture volume remaining after treatment is accomplished by filtering through the treatment soil. The result is the amount that must be stored in the ponding area above the reduced bioretention
area assumed in Step 6. For example, the amount remaining to be stored comparing Step 3 and Step 5 is 292 cubic feet – 219 cubic feet = 73 cubic feet. If this volume is stored over a surface area of 210 square feet, the average ponding depth would be 73 cubic feet ÷ 210 square feet = 0.35 feet or 4.2 inches.

- Check to see if the average ponding depth is between 6 and 12 inches, which is the recommended allowance for ponding in a bioretention facility or flow-through planter.

7. Optimize the Size of the Treatment Measure

- If the ponding depth is greater than 12 inches, a larger surface area will be required. (In the above example, the optimal size of the bioretention area is 190 square feet with a ponding depth of 6 inches.) In order to build conservatism into this sizing method, the Countywide Program recommends that municipalities not approve the design of any bioretention areas or rain gardens that have a surface area that is less than 3 percent of the effective impervious area within the DMA.

In addition to the Excel worksheet for performing the above calculations, Appendix C includes an example of sizing bioretention areas using the combination flow- and volume-based method.

5.2 Applicability of Non-Low Impact Development (LID) Treatment

Since December 1, 2011, the MRP has placed restrictions on the use of non-LID treatment measures. Only Special Projects are allowed some limited use of non-LID treatment measures for stand-alone treatment of stormwater. Special Projects, as defined in Appendix J, are allowed to treat specified percentages of the C.3.d amount of stormwater runoff with vault-based media filters or tree well filters that have a high flow rate. See Appendix J for additional guidance on Special Projects.

Underground vault-based, non-LID treatment measures typically require frequent maintenance to function properly, and experience has shown that because these systems tend to be “out of sight, out of mind,” they often do not receive adequate maintenance. Where underground vaults are allowed, they must be sealed to prevent mosquito access and include suitable access doors and hatches to allow for frequent inspections and maintenance. But even when maintained properly, some types of underground vault systems lack the detention time required to remove pollutants associated with fine particles. See Appendix E for more information regarding inlet filters, oil/water separators, hydrodynamic separators and media filters.
5.3 Using Treatment Trains

Stormwater can be directed to flow through a series of different types of stormwater treatment measures that are each designed to treat different broad categories of stormwater pollutants. These groupings of stormwater treatment measures have been called “stormwater treatment trains” or a “multiple treatment system.” The use of a series of treatment measures is most effective where each treatment measure optimizes the removal of a particular type of pollutant, such as coarse solids and debris, pollutants associated with fine solids, and dissolved pollutants. Targeting specific treatment processes by constituent is referred to as “unit process” design. Each stormwater treatment measure in a treatment train should be sized using the Provision C.3 numeric sizing criteria.

The simplest version and most common use of a treatment train consists of pretreatment prior to the stormwater reaching the main treatment system. For example, bioretention areas may use vegetated buffer strips to settle out sediment before the stormwater enters the bioretention area. This type of pretreatment helps prevent sediment from clogging the bioretention area, which maximizes its life. Another example is when a hydrodynamic separator is used to remove trash and coarse sediment upstream of a media filter or subsurface infiltration system. Note that non-LID treatment measures may be used in the treatment train as long as the last measure in the train is an LID treatment measure.

Another option for a treatment train is to provide upstream storage for a treatment measure which may allow the treatment measure to be reduced in size. For example, a rainwater cistern may be used to store and slowly release water to a bioretention facility. Conversely, the bioretention facility can be used to treat the overflow from the cistern if there is insufficient irrigation or toilet flushing demand to empty the cistern prior to the next rain event.

5.4 Infiltration Guidelines

Infiltration is prioritized by the MRP, and it can be a very cost-effective method to manage stormwater – if the conditions on your site allow. A wide-range of site-design measures and stormwater treatment measures can be used to increase stormwater infiltration and can be categorized as follows:

- **Site design measures** -- such as clustering development or otherwise laying out the site to reduce impervious area, routing drainage from building roofs to landscaped areas, and using pervious pavement.

- **Indirect infiltration** methods, which allow stormwater runoff to percolate into surface soils. Runoff may reach groundwater indirectly, or it may be underdrained into subsurface pipes. Bioretention is an example of indirect infiltration. Unless geotechnical considerations preclude it, all projects should maximize infiltration of stormwater runoff.
through methods such as raising the underdrain in unlined bioretention areas (see Section 6.1).

- **Direct infiltration** methods, which are designed to **bypass surface soils** and transmit runoff directly to subsurface soils, may allow infiltration to groundwater. These types of devices must be located and designed to limit the potential for stormwater pollutants to reach groundwater. Deep infiltration trenches are an example of a direct infiltration method.

The local jurisdiction may require a geotechnical review for your project, or, at a minimum, information regarding the site’s hydrologic soil type. When selecting site design and stormwater treatment measures that promote on-site infiltration, be sure to **follow the geotechnical engineer’s recommendations** based on soil boring data, drainage pattern, and the current requirements for stormwater treatment. The geotechnical engineer’s input will be critical to prevent infiltrating water from damaging surrounding properties, structures and/or public improvements.

**Appendix F** provides additional information to help you determine whether your project site is suitable for using site design and/or stormwater treatment measures that increase stormwater infiltration. Appendix F also describes regulatory requirements that apply to direct infiltration methods, as well as practical tips for design and construction.

### 5.5 Underdrains in Biotreatment Measures

Where the existing soils have a lower infiltration rate than soils specified for a landscaped-based stormwater treatment measure, or “biotreatment measure,” it may be necessary to install an underdrain to allow the treatment measure to function as designed and **prevent the accumulation of standing water**.

Underdrains are perforated to allow water to enter the pipe and flow to the storm drain system. To help prevent clogging, two rows of perforation may be used, and should be installed facing downward. Cleanouts should be installed to allow access to underdrains to remove clogs. **Underdrains should NOT be wrapped in filter fabric**, to help avoid clogging. Underdrains are typically installed in a layer of washed drain rock or Class 2 perm aggregate, beneath high-percolation stormwater biotreatment soils.

Where conditions allow, place the underdrain near the top of the underlying rock layer, to promote infiltration, as shown in technical guidance for specific stormwater treatment measures in Chapter 6.

### 5.6 Technical Guidance for Low-Flow Systems

Although stormwater treatment measures are sized to remove pollutants from flows resulting from frequent, small storms, projects must be designed to handle flows for stormwater treatment and drainage from large infrequent flows to **prevent flooding**. The integration of flood control and stormwater treatment may be accomplished in one of two ways, which are described below.
One option is to have the flows that are larger than those required by the hydraulic sizing criteria (given in Section 5.1) handled within the stormwater treatment measure. However, the design should insure that treatment measures do not re-suspend and flush out pollutants that have been accumulating during small storms, and that stormwater treatment measures do not erode during flows that will be experienced during larger storms. Some treatment measures may be designed to handle flood flows, although they would not be providing much treatment during these flows. The C.3 technical guidance in Chapter 6 for treatment measures that operate in this manner includes design standards to accommodate flood flows associated with larger storms.

Bioretention areas, flow-through planter boxes, and other treatment systems that rely on filtering or infiltrating stormwater through soils must have overflow systems that allow flood flows larger than the increment of flow that can be treated to bypass the stormwater treatment measure. The technical guidance in Chapter 6 for treatment measures that operate in this manner includes design standards for overflow drains or high-flow bypasses.

Another option is to restrict stormwater flows to the treatment measure or bypass high flows around the treatment measure. Since stormwater treatment measures are generally designed to treat only the water from small storm events, bypassing larger flows helps prevent hydraulic overload and resuspension of sediment, and it can also protect stormwater treatment measures from erosion.
Flow splitter devices may be used to direct the design runoff flow into a stormwater treatment measure, and bypass excess flows from larger storm events around the facility into a bypass pipe or channel. The bypass may connect directly to the storm drain system, or to another stormwater treatment measure that is designed to handle high flows. This can be accomplished using a stepped manhole (Figure 5-2) or a proprietary flow splitter (Figure 5-3). As illustrated in Figure 5-3, runoff enters the device by way of the inlet at the left side of the figure; low flows are conveyed to the stormwater treatment measure by way of the outlet pipe at the lower right. Once the treatment measure reaches its design capacity, water backs up in the low-flow outlet pipe and into the flow splitter. When the water level in the flow splitter reaches the bypass elevation, stormwater begins to flow out the overflow pipe, shown at the upper right of the figure, bypassing the stormwater treatment measure. The bypass generally functions by means of a weir inside the flow splitter device.

5.7 Plant Selection and Maintenance

Selecting the appropriate plants and using sustainable, horticulturally sound landscape design and maintenance practices are essential components of a successful landscape-based stormwater treatment measure.

Plant Selection Guidance
Plant selection must consider the type of development and location, uses on the site and an appropriate design aesthetic. Ideally, a Landscape Architect will be involved as an active member of the design team early in the site design phase to review proposed stormwater measures and coordinate development of an integrated solution that responds to all of the various site goals and constraints. In some cases, one professional will design a stormwater control, while another designs the rest of the landscaping. In these situations it is critical for the professionals to work together very early in the process to integrate their designs. Appendix B provides user-friendly guidance in selecting planting appropriate to the landscape-based stormwater treatment measures included in Chapter 6.

Bay Friendly Landscaping
Bay-friendly landscaping is a whole systems approach to the design, construction and maintenance of the landscape in order to support the integrity of the San Francisco Bay watershed. Project sponsors are encouraged to use landscape professionals who are familiar with and committed to implementing Bay-Friendly landscaping practices from the initial plant selection through the long-term maintenance of the site. Appendix B summarizes Bay Friendly
Landscaping Practices that may be implemented to benefit water quality of the Bay and its tributaries, based on the Bay-Friendly Landscaping Guidelines (available at www.rescapeca.org).

**Integrated Pest Management**

Integrated pest management (IPM) is a holistic approach to mitigating insects, plant diseases, weeds, and other pests. Projects that require a landscaping plan as part of a development project application are encouraged to use IPM, as indicated in each agency’s source control measures list. *Avoiding pesticides and quick release synthetic fertilizers* is particularly important when maintaining stormwater treatment measures to protect water quality.

IPM encourages the use of many strategies for first preventing, and then controlling, but not eliminating, pests. It places a priority on fostering a healthy environment in which plants have the strength to resist diseases and insect infestations, and out-compete weeds. Using IPM requires an understanding of the life cycles of pests and beneficial organisms, as well as regular monitoring of their populations. When pest problems are identified, IPM considers all viable solutions and uses a combination of strategies to control pests, rather than relying on pesticides alone. The least toxic pesticides are used only as a last resort. More information on IPM is included in Appendix B.

**Wetland Regulations and Treatment Measures**

The Water Board’s “Policy on the Use of Constructed Wetlands for Urban Runoff Pollution Control” (Resolution No. 94-102) recognizes that stormwater treatment wetlands that are constructed and operated pursuant to Resolution 94-102 and are constructed outside a creek or other receiving water are stormwater treatment systems, and, as such, properly maintained stormwater treatment measures are not waters of the United States subject to Sections 401 and 404 of the federal Clean Water Act.

**Water Efficient Landscaping Requirements**

The California Water Conservation in Landscaping Act of 2010, and the 2015 amendments of Title 23, California Code of Regulations, Chapter 2.7 Model Water Efficient Landscape Ordinance, Sections 490 through 495, requires municipalities to adopt, by December 1, 2015, landscape water conservation ordinances that are at least as effective in conserving water as the 2015 update of the Model Water Efficient Landscape Ordinance prepared by the Department of Water Resources. The Model Ordinance automatically went into effect, on December 1, 2015, four individual municipalities that had not adopted a comparable local ordinance. For local land use agencies working together to develop a regional water efficient landscape ordinance, the reporting requirements of Model Ordinance became effective December 1, 2015, and the remainder of this ordinance went into effect February 1, 2016.

The updated Model Ordinance applies to (1) new construction projects with an aggregate landscape area equal to or greater than 500 square feet requiring a building or landscape permit, plan check or design review; (2) rehabilitated landscape projects with an aggregate landscape area equal to or greater than 2,500 square feet requiring a building or landscape permit, plan check, or design review; (3) existing landscapes that were installed before December 1, 2015, and are over 1 acre in size. The Green Building Code also requires water budgeting for non-residential projects consistent with the Ordinance. Contact the municipality to
determine whether your project is subject to the updated Model Ordinance or other water efficient landscaping ordinance.

5.8 Mosquito Control

Some types of stormwater treatment measures are designed to hold water, and even treatment measures that are designed to eliminate standing water between storms may have the potential to retain standing water if they are not properly designed, constructed and maintained.

To reduce the potential for stormwater treatment measures to lead to mosquito problems, the Clean Water Program developed a Vector Control Plan, which describes the need to include physical access for mosquito control staff to monitor and treat mosquitoes, and includes guidance for designing and maintaining stormwater treatment measures to control mosquitoes. The California Department of Health (2010) has identified a four-day maximum allowable water retention time for stormwater treatment facilities. With the exception of certain stormwater treatment measures designed to hold permanent water (e.g., CDS units and wet ponds), all treatment measures should drain completely within four days to effectively suppress vector production. Please note that the design of stormwater treatment measures does not require that water be standing for four days. During four days after a rain event, standing water is allowable but not required for the stormwater treatment measure to function effectively. Treatment measure designs and maintenance plans must include mosquito control design and maintenance strategies from the Vector Control Plan, included in Appendix G.

5.9 Incorporating Hydromodification Management

In addition to requiring stormwater treatment, the MRP also requires that stormwater runoff be detained and released in a way that prevents increased creek channel erosion and siltation in susceptible areas. The amount of stormwater flow and the duration of flows that cause erosion must be limited to match what occurred prior to the proposed development or re-development. These hydromodification management (HM) requirements apply to projects that create one acre or more of impervious surface in most areas of Alameda County. See Chapter 7 for more information.

The HM requirements have been in effect since 2007 and may be required on your project in addition to stormwater treatment, low impact development, and flood control requirements (if any). To prevent hydromodification, HM facilities are designed to match pre-project flow durations for a range of flows from 10 percent of the two-year storm peak flow up to the ten-year storm peak flow. This is different from the sizing criteria that are used for stormwater treatment and LID measures, and from the design criteria used for flood control facilities.
To help applicants meet the HM requirements, the Clean Water Program developed the Bay Area Hydrology Model (BAHM) with assistance from the municipal stormwater programs in Santa Clara and San Mateo Counties. You can use the BAHM to automatically size stormwater detention measures such as detention vaults, tanks, basins and ponds for Flow Duration Control of post-project runoff (go to www.clearcreeksolutions.info/ftp/public/downloads/BAHM2013/bahm2013.msi to download the BAHM). Chapter 7 provides more detail on HM requirements and the BAHM.

5.10 Getting Water into Treatment Measures

Stormwater may be routed into stormwater treatment measures using *sheet flow or curb cuts*. The following pages from the San Mateo County Sustainable Green Streets and Parking Lots Design Guidebook show common curb cut types. An 18-inch width at bottom of curb (see Figure 5-6) is recommended for curb cuts, to avoid clogging. To avoid erosion, cobbles or other energy dissipater is recommended. A minimum two-inch drop in grade between the impervious surface and the finish grade of the stormwater treatment facility is recommended. This drop in grade needs to take into consideration the height of any vegetation.

*Figure 5-5: Cobbles are placed at the inlet to this stormwater treatment measure in Fremont, to help prevent erosion.*
Standard Curb Cut: Design Guidance

- Opening should be at least 18 inches wide; for smaller facilities 12” width may be allowed subject to municipal approval.
- Curb cut can have vertical sides or have chamfered sides at 45 degrees (as shown).
- Works well with relatively shallow stormwater facilities that do not have steep side slope conditions.
- Need to slope the bottom of the concrete curb toward the stormwater facility.
- Allow a change in elevation of 4 to 6 inches between the paved surface and biotreatment soil elevation, so that vegetation or mulch build-up does not obstruct flow.
- Provide cobbles or other energy dissipater to prevent erosion.

Figure 5-6: This standard curb cut at parking lot rain garden has 45 degree chamfered sides.

Figure 5-7: Standard curb cut: section view (Source: San Mateo Countywide Water Pollution Prevention Program [SMCWPPP] 2009)

Figure 5-8: Standard curb cut: plan view (Source: SMCWPPP 2009)
Standard Curb Cut with Side Wings: Design Guidance

- Opening should be at least 18 inches wide; for smaller facilities 12” width may be allowed subject to municipal approval.
- Works well with stormwater facilities that have steeper side slope conditions.
- Need to slope the bottom of the concrete curb toward the stormwater facility.
- Allow a change in elevation of 4 to 6 inches between the paved surface and biotreatment soil elevation, so that vegetation or mulch build-up does not obstruct flow.
- Provide cobbles or other energy dissipater to prevent erosion.

Figure 5-9: The side wings of this standard curb cut help retain the side slope grade on each side of the curb cut opening.

Figure 5-10: Standard curb cut with side wings: cut section view (Source: SMCWPPP 2009)

Figure 5-11: Standard curb cut with side wings: plan view (Source: SMCWPPP 2009)
Wheelstops allow water to flow through frequently spaced openings.

Wheelstops are most common in parking lot applications, but they may also be applied to certain street conditions.

Need to provide a minimum of 6 inches of space between the wheelstop edge and edge of paving. This is to provide structural support for the wheelstop.

Allow a change in elevation of 4 to 6 inches between the paved surface and biotreatment soil elevation, so that vegetation or mulch build-up does not obstruct flow.

Provide cobbles or other energy dissipater at the wheel stop opening to prevent erosion.

Figure 5-12: Stormwater runoff enters the stormwater facility through the 3-foot space between these wheelstops. The design could be improved by providing more of a drop in grade between the asphalt and landscape area.

Figure 5-13: Opening between wheelstop curbs: section view (Source: SMCWPPP 2009)

Figure 5-14: Opening between wheelstop curbs: plan view (Source: SMCWPPP 2009)
Grated Curb Cut: Design Guidance

- Grated curb cuts allow stormwater to be conveyed under a pedestrian walkway. The curb cut opening should be at least 18 inches wide; 12” may be allowed for smaller facilities subject to municipal approval.
- Grates need to be ADA compliant and have sufficient slip resistance.
- A 1-to-2 inch high asphalt or concrete berm should be placed on the downstream side of the curb cut to help direct runoff into the curb cut.
- Allow a change in elevation of 4 to 6 inches between the paved surface and biotreatment soil elevation, so that vegetation or mulch build-up does not obstruct flow.

Figure 5-15: A grated curb cut allows stormwater to pass under a pedestrian egress zone to the stormwater facility.

Figure 5-16: Grated curb cut: section view (Source: SMCWPPP 2009)

Figure 5-17: Grated curb cut: plan view (Source: SMCWPPP 2009)